BANKABLE PILOT PLANTS

Fully Integrated Simulations of Continuous Operating Conditions
GS ADVANCED MINERALOGY LABS

- Global leader
  - Certification & Verification
  - Inspection & Monitoring
  - Sampling & Testing
  - Risk management
  - Public company
  - Market cap $11.85B, no debt
  - 65,000 people
  - 650 labs in 7 industrial segments
  - 2000 offices
SGS MINERALS SERVICES

- Laboratory analysis
- On-site services
- Metallurgical testing
- Mechanical sampling systems
- Inspection
- Sampling
OUR ROLE IN MANAGING RISK

- Economic risk
- Technical risk

SGS Minerals Services

Piloting
PILOT PLANTS

- Real-time integrated demonstration of processing circuit using expected feed, reagents and equipment.
- Pertinent for mining projects & industrial process design
- Pilot plants prove critical attributes of a commercial plant thus allow evaluation and troubleshooting
- Industry standard due diligence and risk reduction
INTEGRATED PILOT PLANTS

- Beneficiation
- PAL Circuit
- Neutralization, CCD
- Precipitation, SX-EW

- 24/7 operation possible
- 150 dedicated staff, 70-80 hr weeks
- Metallurgy, mineralogy, analytical, process control, environmental
- On-site maintenance (electrical, mechanical, instrumentation)
VALUE OF INTEGRATED PILOT PLANTS

- Demonstrate anticipated operations
- Integrate unit processes in real time
- Review impact of feed variability
- Assess recycle streams
- Identify potential problems (operating, automation, corrosion, maintenance)
- Confirm energy needs, water balance and treatment, reagent consumption & equipment sizing
- Prove product quality and generate market samples
- Mitigate environmental concerns
DECADES OF EXPERIENCE

- 3-6 integrated pilot plants/year for 30 years
- 10 off-site, in-plant pilot plants
- 15 broad scope, in-plant services contracts
- 8 on-site start-ups
<table>
<thead>
<tr>
<th>Boleo Cu, Au</th>
<th>Farrallon Zn, Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skye Resources Ni</td>
<td>Nui Phao, Tiberon W, F, Bi</td>
</tr>
<tr>
<td>MacKenzie Bay V</td>
<td>Montcalm Ni, Cu</td>
</tr>
<tr>
<td>Antamina Cu, Zn</td>
<td>Winnaarshoek, Impala PGE</td>
</tr>
<tr>
<td>PolyMet/NorthMet many</td>
<td>Pebble Au</td>
</tr>
<tr>
<td>Key Lake (on-site) NiCo As</td>
<td>Oyu Tolgoi Au, Cu</td>
</tr>
<tr>
<td>Voiseys Bay Ni Cu</td>
<td>Pascua-Lama Au</td>
</tr>
<tr>
<td>Sepon, Oxiana Cu, Au, Ag</td>
<td>Pueblo Viejo Au</td>
</tr>
<tr>
<td>Avalon Ventures REE</td>
<td>Pogo Au</td>
</tr>
<tr>
<td>North American Palladium PGE</td>
<td></td>
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TYPICAL TIMELINE OF PROJECT DEVELOPMENT

- Characterize ore
  - Grade, mineralogy, beneficiation, settling, viscosity, geometallurgy

- Bench-scale testwork
  - Linked to process design criteria, variability testing, geometallurgy

- Process selection
  - Flowsheet development and optimization

- Pilot-scale testwork
  - Confirm design criteria on composites of various ore types
  - Create samples of final products for market evaluation.
  - Provide bankable assessment of operational viability
## PILOT PLANT PREPARATION AND MANAGEMENT

### Expertise
- Mineral Processing
- Hydrometallurgy
- Geometallurgy
- Environment
- Analytical
- Mineralogy
- Interdisciplinary

### Facilities
- Laboratories
- Pilot Plant
- Analytical Laboratory
- Advanced Mineralogy Laboratory

### Pilot plant management
- Project budgeting
- Pre-pilot testwork
- Flowsheet development
- Planning
- Design
- Construction
- Operation
- Data Collection
- Reporting
- Client relations

### Services
- Maintenance
- Purchasing
- IT support
- Health, Safety and Environment
- Administrative support

### Critical mass
- Qualified workspace ~ 80+ staff
- 24/7 analytical coverage
- Dedicated trades
# OPERATIONAL MANAGEMENT

## Technical areas of expertise

**Senior Metallurgists/ Project Managers/ Consultants**

<table>
<thead>
<tr>
<th>Administration</th>
<th>Leaching- POX autoclave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budgeting</td>
<td>Separations/ CCD/ Rheology</td>
</tr>
<tr>
<td>Resources</td>
<td>SX-EW, Purification</td>
</tr>
<tr>
<td>Schedule</td>
<td>Overall technical and data management</td>
</tr>
</tbody>
</table>

## Shift coverage 24/7

- Circuits
- Shift leaders/ technologists

## Front end – feed preparation and leaching

- Neutralization – CCD
- SX- EW
- Iron removal
- Precipitation circuits
- Final treatment – process water make-up

## Data acquisition 24/7

- Reporting – daily Client feedback
PROJECT MANAGEMENT OVERVIEW

Client

Project Manager

SGS
Admin Manager

Budget
Infrastructure/Resources
Scheduling/Microsoft Projects

SGS
Technical Manager

All technical details
Unit design
Operating parameters
Technical client liaison

Technical Submanagers

Unit 1
Unit 2
Unit 3
Unit 4
DATA MANAGEMENT

VIRTUAL WORK SPACE

DCS Instrument data

LIMS Lab data

OPERATIONS Data entry

Locked

Locked

Locked

Client

Website

Technical Manager
LOGISTICS

- Typical sample size: 200 kg – 2 tonnes
- Minimum project time: 3 months
  - Planning: 2 weeks
  - Set-up: 1-2 weeks
  - Piloting: 3-5 weeks
  - Reporting 4-8 weeks
- Health and safety key considerations
- Ambient, heated, frozen sample storage options
- Sample ownership remains with you
ON-LINE ANALYSIS

- XRF
- Particle Size Analysis
DIAGNOSTICS & CALIBRATION

- XRF
- Particle Size Analysis
LOGISTICS

- Quick connects
- Data entry
- Barcoded samples
HEALTH AND SAFETY

- HazOp meetings
- PPE and Access Cards
ACCREDITED ANALYTICAL SERVICES

- Analytical
- Environmental
- Mineralogy

- Respected Quality – ISO 17025
- Numerous accredited labs in Canada, South Africa, South America, Australia, Russia, China
SGS

ADV. MINERALOGY SERVICE CENTRE

- Lab network providing automated process mineralogy services to high volume users.
  - QEM Scan (6 ys experience, 30+ projects)
  - XRD, SEM, electron microprobe
  - Image analysis
  - Petrography (PTS, PS), photography

- Applications
  - Ore-type definition
  - Plant control and optimization
  - Environmental and mine planning
  - Economic analysis
ADVANCED EXPERT SYSTEMS

- Expert system = knowledge base + reasoning engine
  Mimics human thought process

- Applications
  - Process control
  - Simulation and modeling
  - Scheduling and logistics
  - Advanced process control
  - Asset management
  - Data hosting and analysis
SITE SECURITY

- 24/7 security patrols
- Caging of products or site
- Final product can be secured
PLANT SECURITY

- Depends on client requirements
  - Secure access facility
  - Video surveillance of key areas
  - Tapes kept as required
DATA SECURITY AND IP

- Data Security and Access
- Intellectual Property
NEXT STEP: ON-SITE OPERATIONS

- **Plant services**
  - Commissioning
  - Management
  - Training

- **Laboratory services**
  - Design
  - Supply and outfitting
  - Operation
  - Training
  - Metallurgical accounting
Pre-planned allowances and flexibility

- Changes CONTROL the success of piloting game, must preplan. Allow for:
  - sample variability
  - key parameter adjustment
  - recycle streams flowrates

- Design, sizing and construction of equipment, piping and peripherals - adjusting residence times in ALL circuits

- Flexibility decreases with stage– from pre- to full-feasibility.
No one planned to fail. They failed to plan.

- Written plan
- Checklist
- Update
- Manage

1. Transfer MetSim data/test data
2. Determine pilot plant flow rates
3. Verify mass balance
4. Define: Residence time, Tank size and numbers, Surge volume, Cycle times
5. Produce detailed unit operations sequence
6. Select "off the shelf" equipment - tanks, pumps, sensors, peripherals...
7. Define control requirements
8. Selection of adequate flowrate measurement devices for gases and liquids
9. Design project-specific equipment - tanks, thickeners/ CCD, "exotics", etc.
10. Define reagent requirements and order, include gas reagents
11. Produce Floor plan - request Client review if necessary
12. Final review before construction - include Client input
13. Construction
14. Attach instrumentation and control
15. Define detailed operating procedures
16. Define operating data logging requirements
17. Design sampling schedule, include sampling types
18. Design material management sheets
19. Define IT requirements
20. Produce first draft of pilot plant operations plans and submit to client for approval
21. General review - include Client input
22. Define Health and Safety requirements, including HAZOP
23. Engineers training session
24. Key personnel training session
25. All personnel training session and HAZOP
FACTORS AFFECTING SUCCESS

- Sample
- Money, time, human resources
- Work scope vs. expectations and "moving targets"
- Severe “under-testing” at bench scale
- Key metallurgical expertise
- Technical advances